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The impact of standard semiconductor fabrication processes on polycrystalline Nb thin film surfaces

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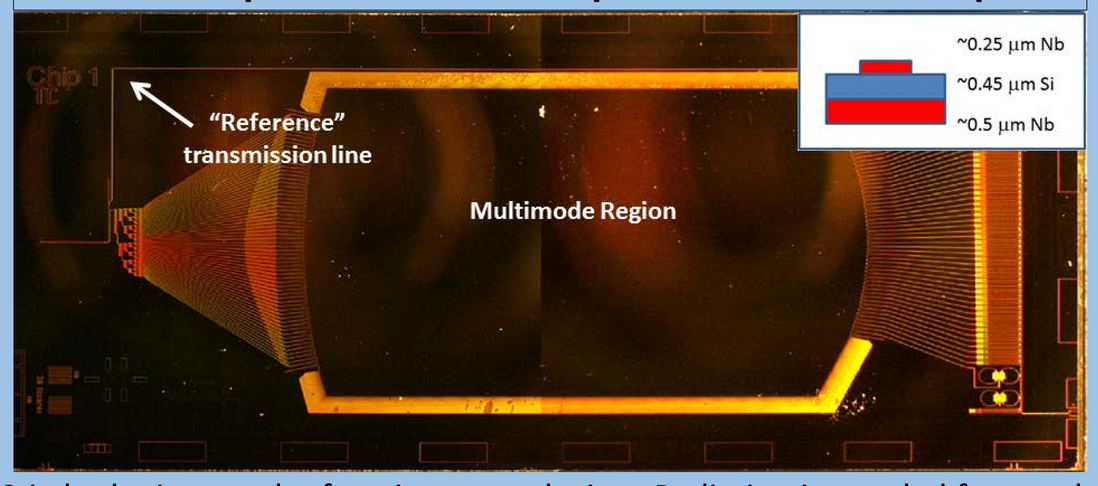
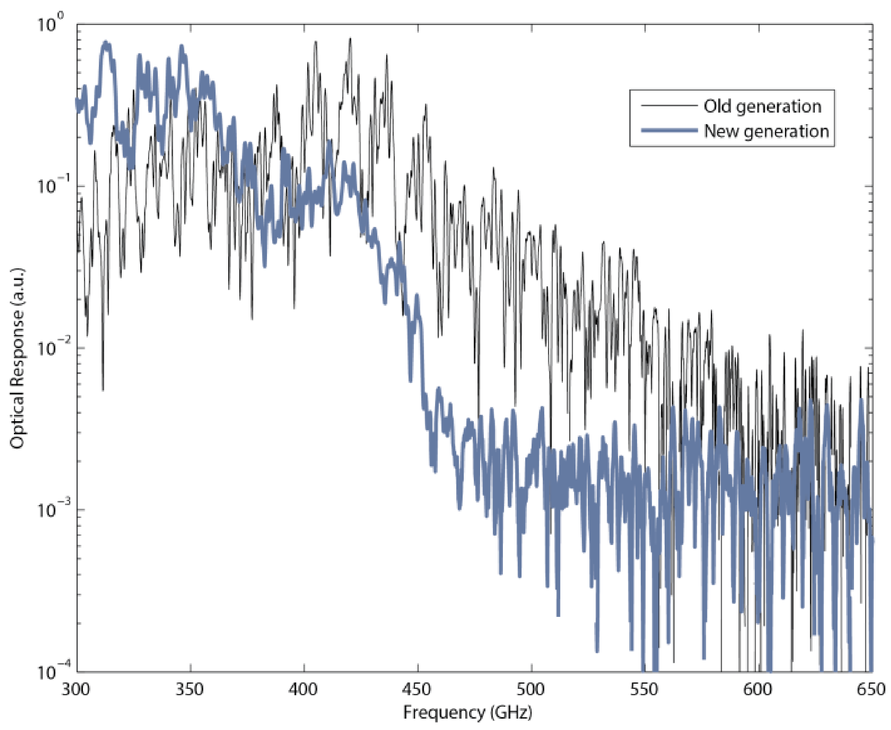
Polycrystalline Nb thin films are extensively used for microwave kinetic inductance detectors (MKIDs) and superconducting transmission line applications. The microwave and *mm*-wave loss in these films is impacted, in part, by the presence of surface nitrides and oxides. In this study, glancing incidence x-ray diffraction was used to identify the presence of niobium nitride and niobium monoxide surface layers on Nb thin films which had been exposed to chemicals used in standard photolithographic processing. A method of mitigating the presence of ordered niobium monoxide surface layers is presented. For a given fabrication process, we have both the x-ray diffraction data of the surface chemistry and a measure of the *mm*-wave and microwave loss, the latter being made in superconducting resonators.

Micro-Spec: A mm-Wave Spectrometer on a Chip



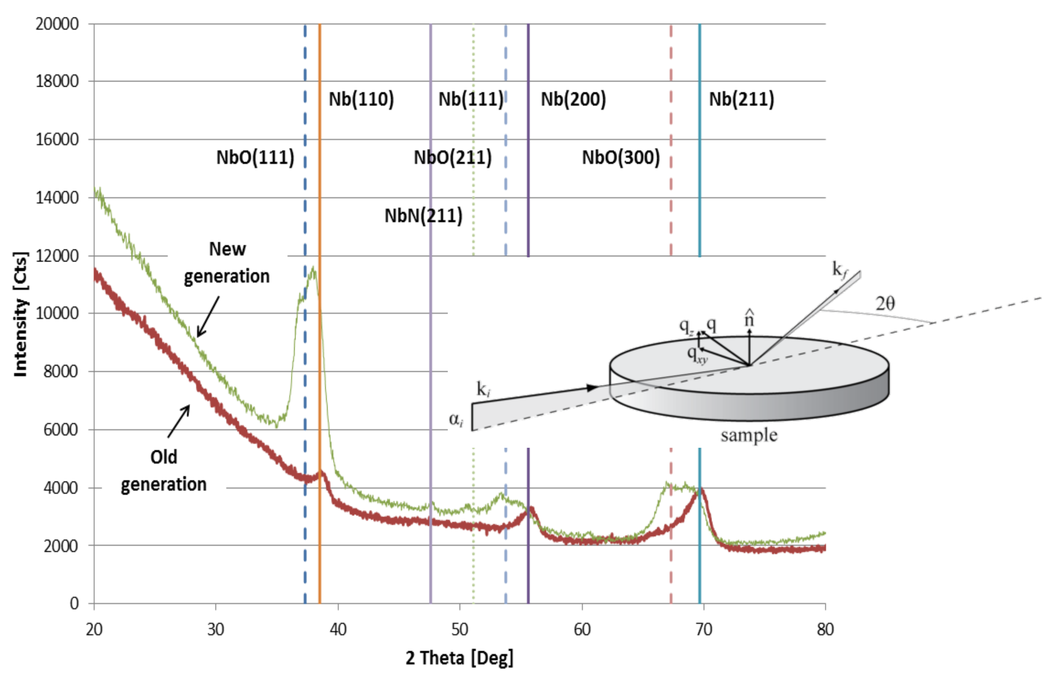
Stitched micrograph of a micro-spec device. Radiation is coupled from a slot antenna to a reference microwave kinetic inductance detectors (MKID) via a transmission line with microstrip geometry. Inset: A cross section schematic of the "reference" transmission line and multimode region.

Transmission Through Micro-Spec Reference Transmission Line



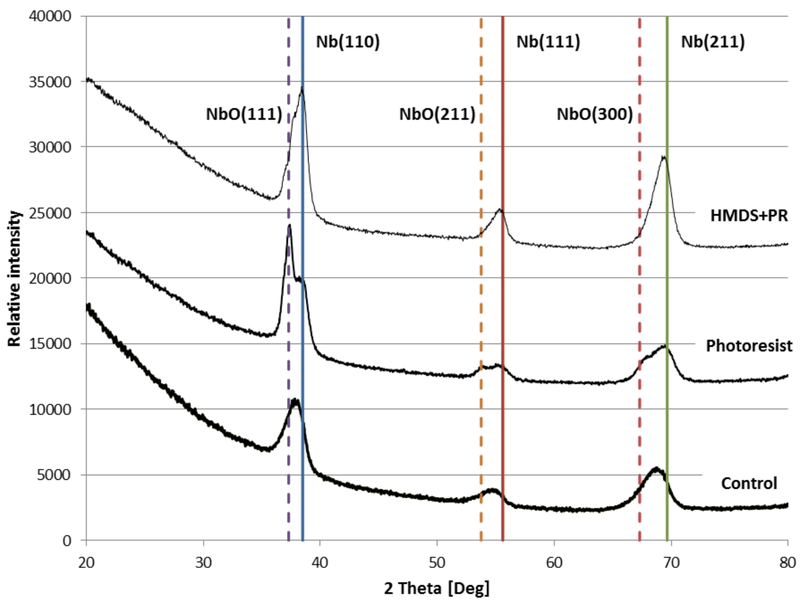
Spectral response of the reference MKID on two Micro-Spec devices, in which the transmission line was 37 mm long. The top side (of the c-Si dielectric) circuitry for the old and new generation devices was exposed to different chemicals.

Glancing Incidence X-ray Diffraction of the Micro-Spec Multimode Region



Glancing incidence (α=0.3° ⟺ x-ray penetration depth in Nb~5 nm) x-ray diffraction patterns taken from the multimode regions on two micro-spec devices. The diffraction patterns of all the new generation devices (n=4 on separate wafers) had distinct diffraction peaks, which corresponded to niobium monoxide.

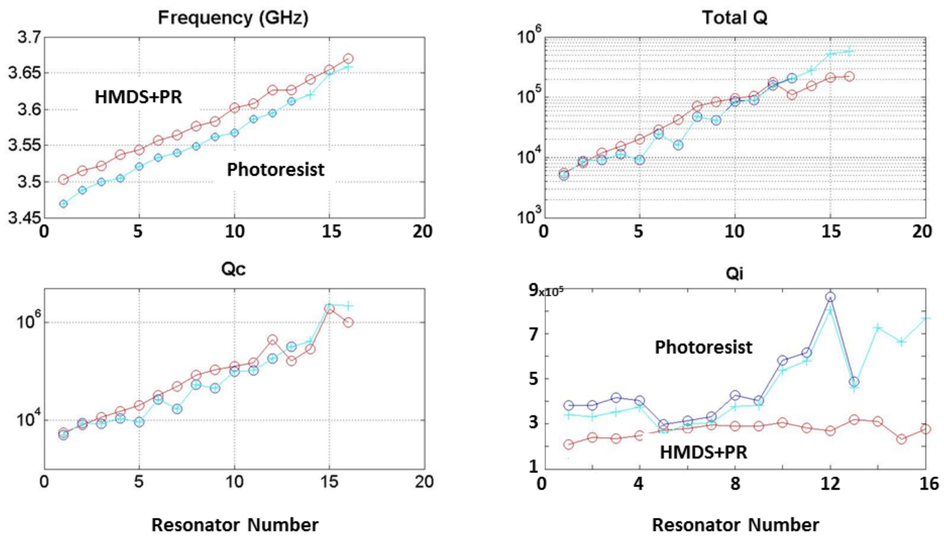
Glancing Incidence X-ray Diffraction of Nb Thin Films Exposed to Standard Chemicals used in Fabrication



Exposure of Nb thin films (with a native Nb_2O_5 oxide layer*) sputter deposited on Si(001) to S-1811 photoresist (which was baked and subsequently removed) resulted in the presence of an ordered NbO phase. Applying HMDS under the PR appears to have mitigated this effect. The carbonyl group in the PGMEA (contained in the PR) was believed to be responsible for the formation of ordered NbO.

*The Nb2O5 thickness was ~3 nm.

Characterization of Superconducting Nb Resonators with Co-planar Waveguide Geometry



CPW Nb thin film resonators were fabricated on the same fz Si(001) wafer. One half of the wafer was exposed to photoresist and the other was passivated with HMDS prior to resist exposure. The measurements were taken at 165 mK with -60 dBm of power.

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